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(71) Applicant(s)
British Gas plc

(Incorporated in the United Kingdom)

Rivermill House, 152 Grosvenor Road, LONDON, SW1V 3JL, United Kingdom

(72) Inventor(s)
David Michael Sutton
Colin Smith

(74) Agent and/or Address for Service
David J Morgan
British Gas plc, 59 Bryanston Street, LONDON, W1A 2AZ, United Kingdom

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UK CL (Edition L) F4T THC THD THG, G1A AHP AMF
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Online databases :WPI.

(54) **Detecting air/fuel gas ratio in heating appliance.**

(57) Apparatus is provided for detecting the ratio of air to fuel gas in a combustible mixture supplied to a first or main burner 1. The apparatus comprises a second or pilot burner 2 which provides a flame which, in use, is located in the path of combustion products leaving the main burner 1. A photoelectric cell 3 is provided for s nsing the intensity of light emission from the pilot burner flame 4 while the main burner 1 is firing and forms part of electrical circuitry which provides an output voltage signal (+Vout) the level of which varies with the ratio of air to fuel gas in the mixture supplied to the main burner 1. This signal controls the speed of a fan to adjust air flow to the main burner.

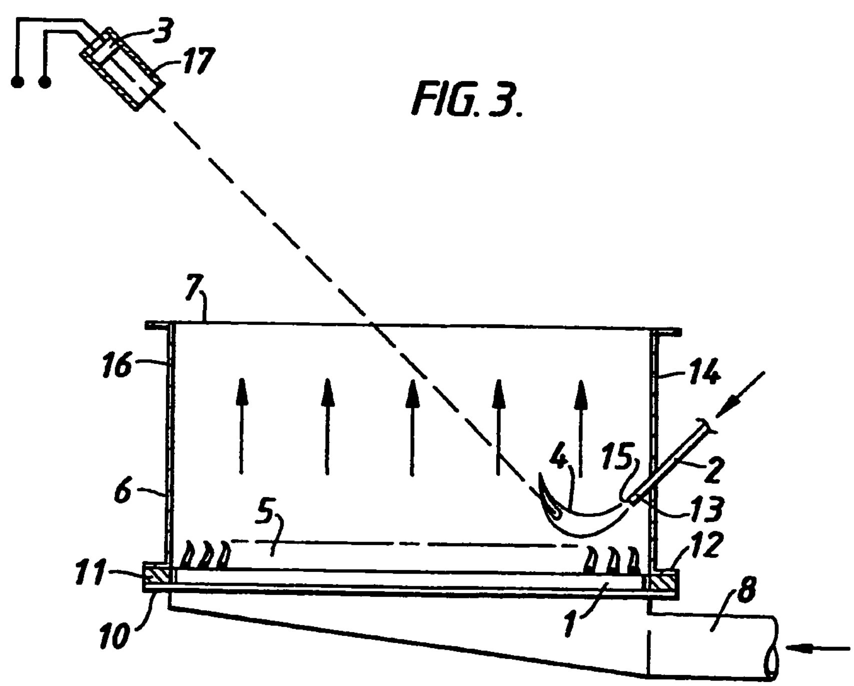

FIG. 3.

At least one drawing riginally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print incorporates corrections made under Section 117(1) of the Patents Act 1977.

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FIG. 1.

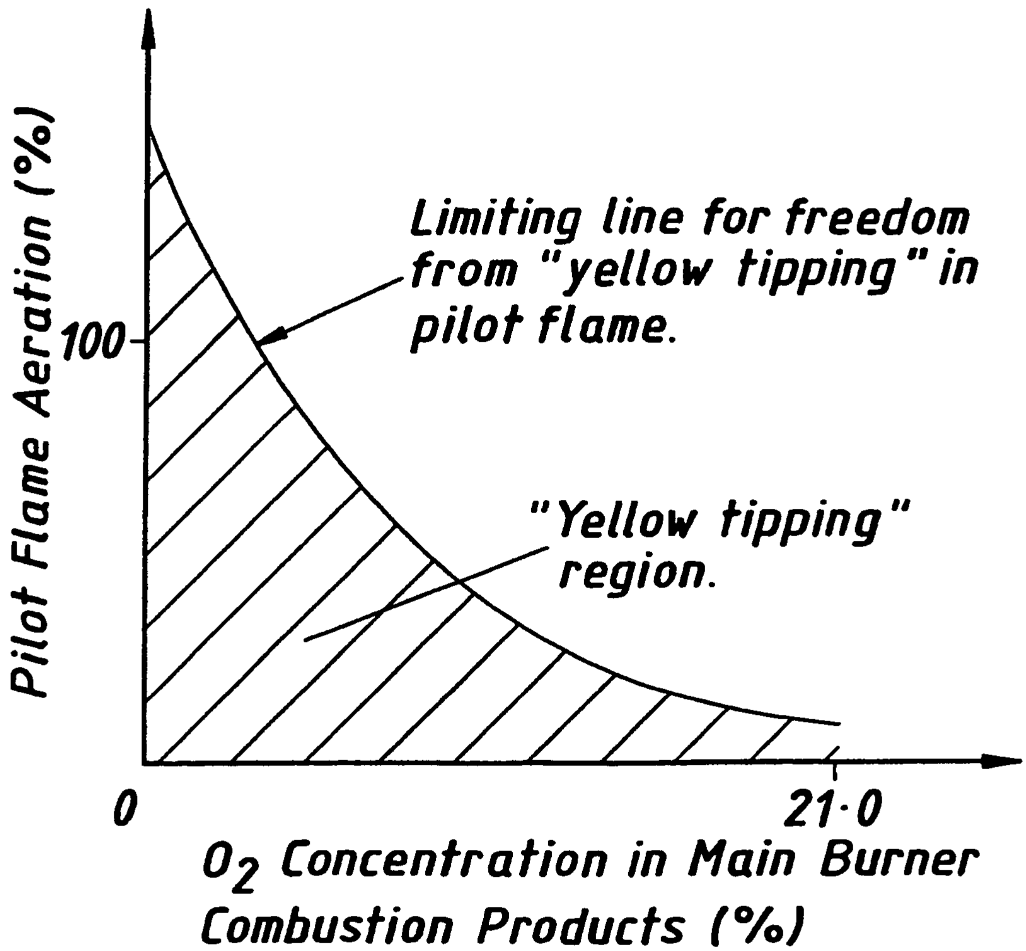
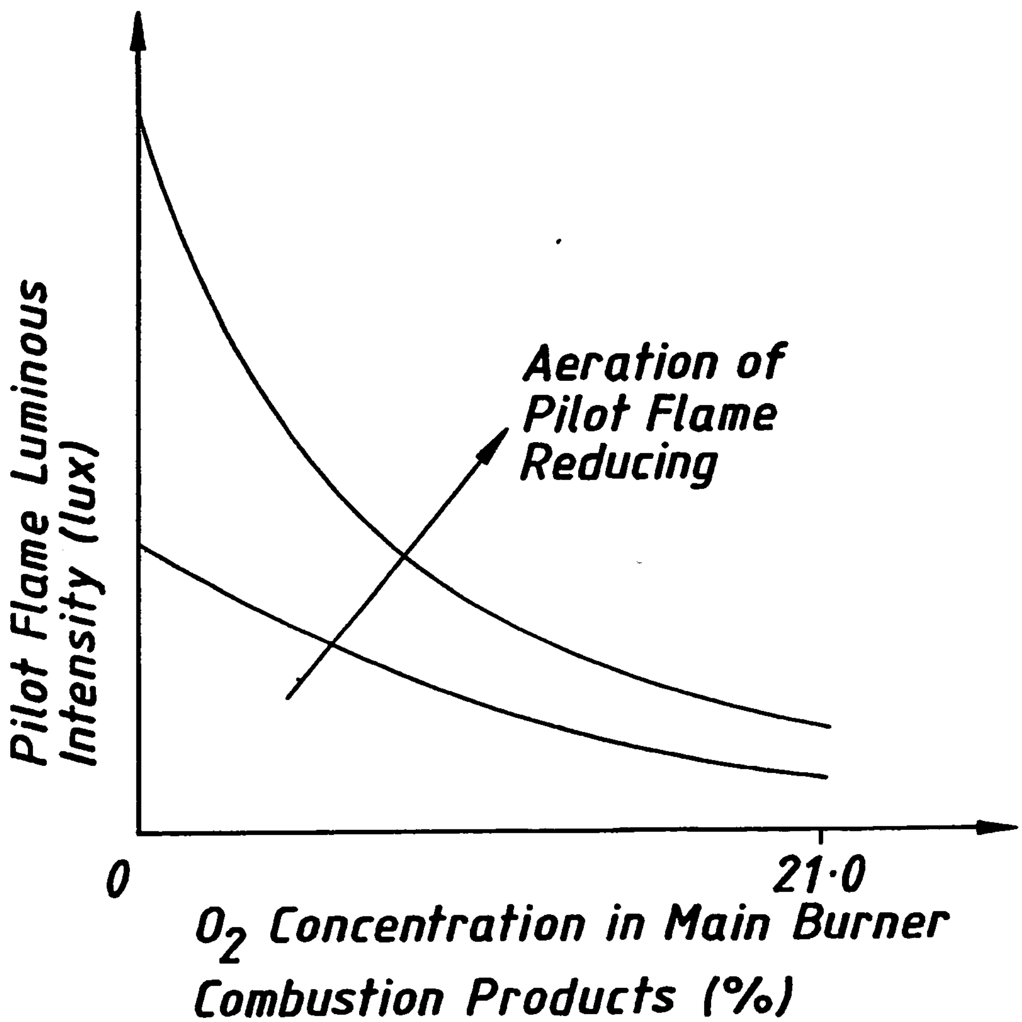

Limiting line for freedom from "yellow tipping" in pilot flame.
"Yellow tipping" region.
Pilot Flame Aeration (%)
100
0
21·0
O_2 Concentration in Main Burner Combustion Products (%)

FIG. 2.


Pilot Flame Luminous
Intensity (lux)
Aeration of
Pilot Flame
Reducing
0
21·0
O_2 Concentration in Main Burner
Combustion Products (%)

20 -7 93

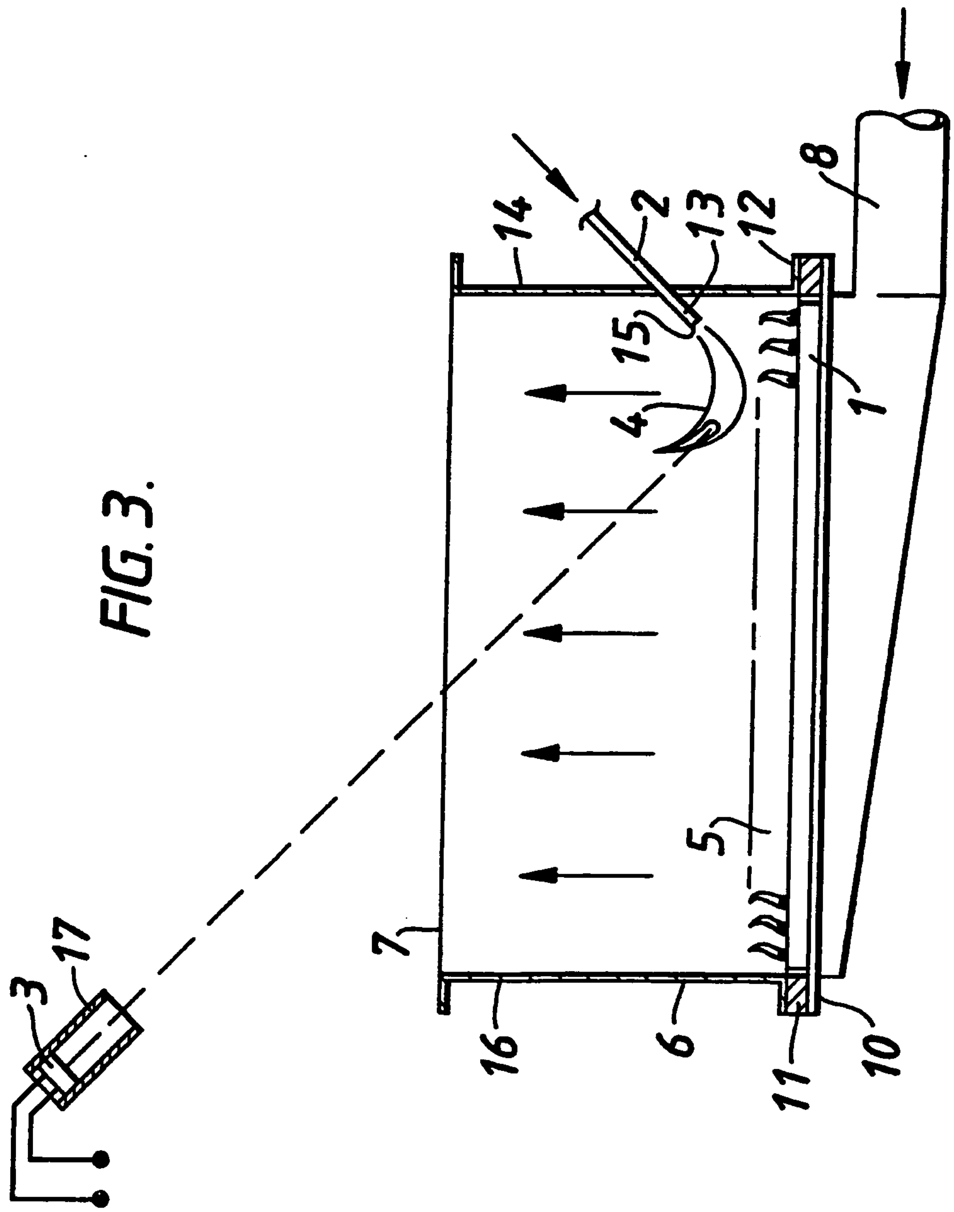


FIG. 3.

20 +7 93

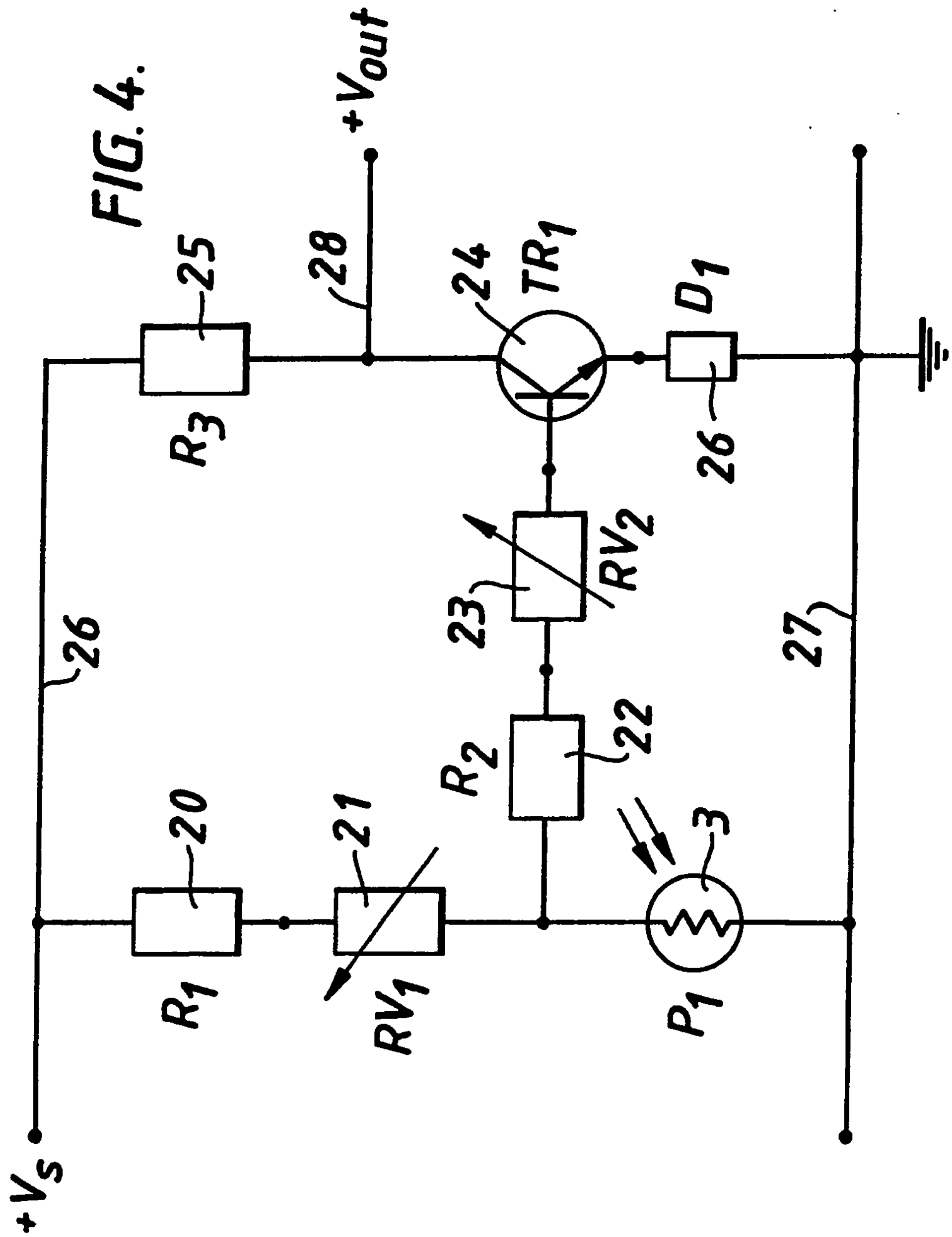


FIG. 4.

FIG. 5.

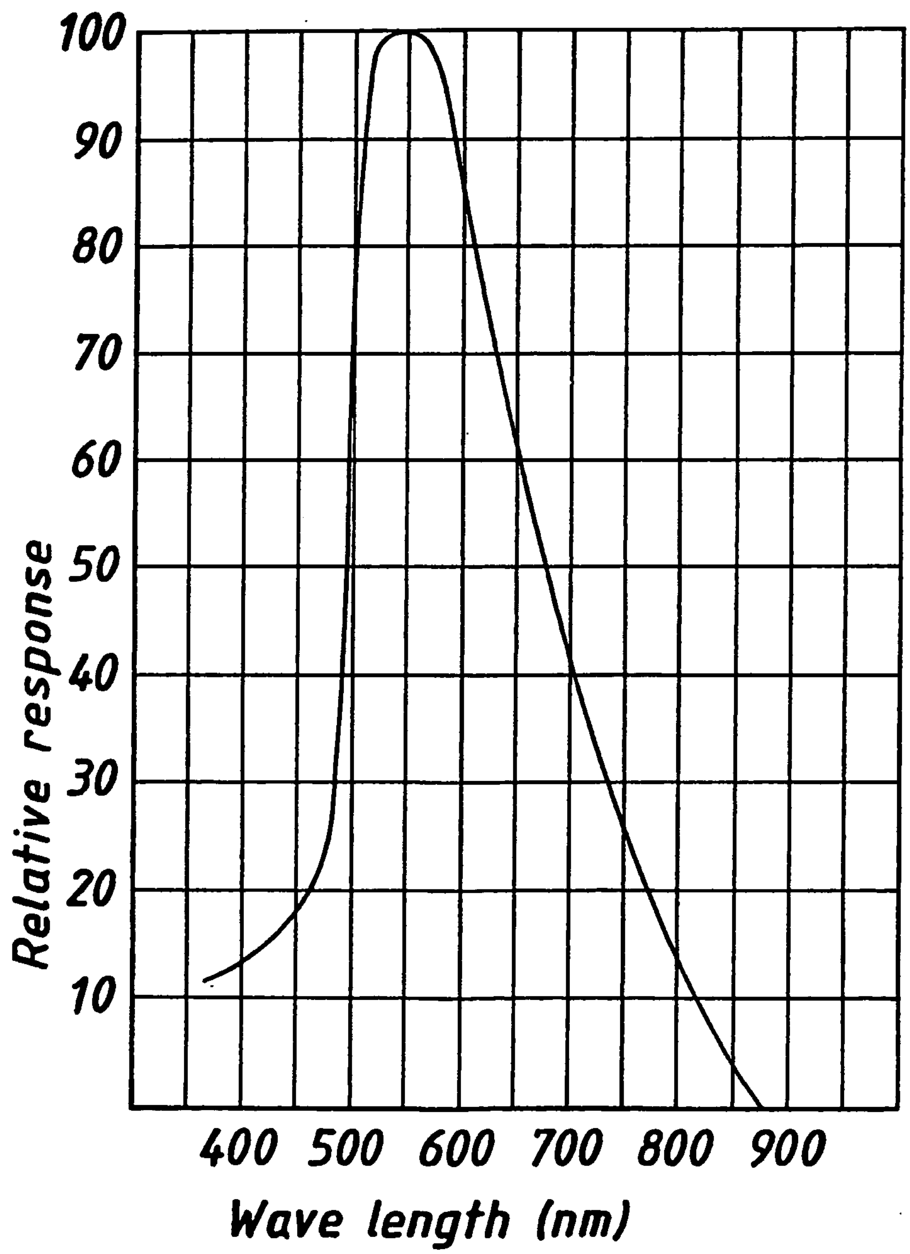

100
90
80
70
60
50
40
30
20
10
Relative response
400 500 600 700 800 900
Wave length (nm)

FIG. 6.

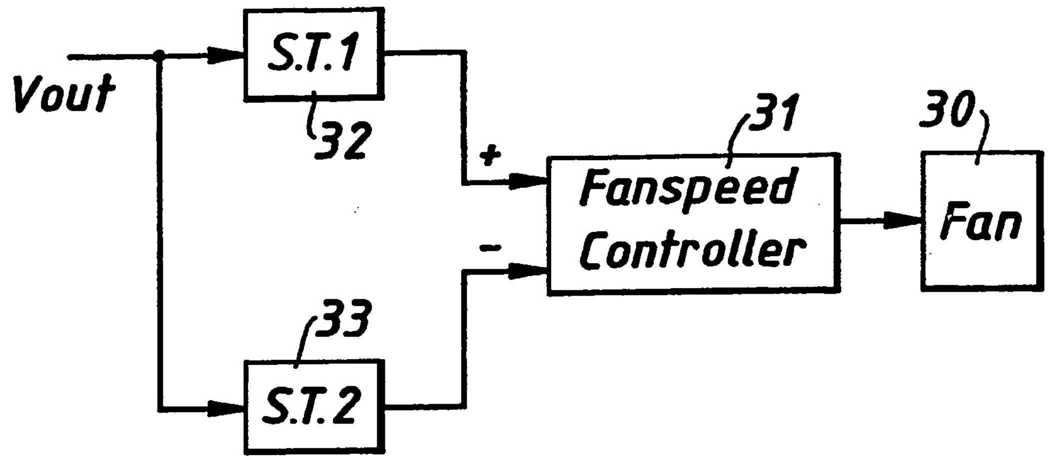
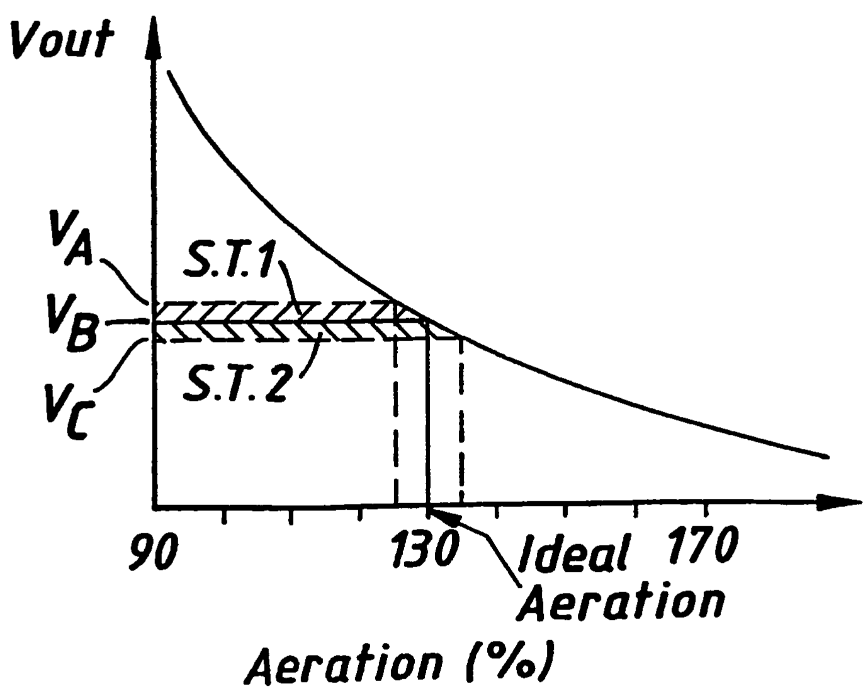

Vout
S.T.1
32
S.T.2
33
+
−
Fanspeed Controller
31
Fan
30

FIG. 7.


Vout
V_A
V_B
V_C
S.T.1
S.T.2
90
130
170
Ideal Aeration
Aeration (%)

APPARATUS FOR DETECTING THE EFFECTIVE RATI F AIR TO FUEL GAS IN A COMBUSTIBLE MIXTURE

The present invention relates to apparatus for detecting the ratio of air to fuel gas in a combustible mixture supplied to a first burner in a heating appliance.

Intensified concern over environmental issues such as global warming has resulted in legislative and market-driven requirements regarding the thermal efficiency of and pollutant emission from gas-fired domestic heating appliances. This has led to interest in the use of fan-assisted fully-premixed burners in place of the simpler partially-aerated type at present employed. By thoroughly mixing with the gas, upstream of the flame all the air supplied for combustion, fully-premixed burners can operate satisfactorily with a much lower provision of excess air than can burners of the partially-aerated type. This feature allows the heating appliance to extract a greater proportion of the heat released by the combustion process without any increase in the size of the heat exchanger. In addition, when operated suitably, fully-premixed burners generate very much lower concentrations of pollutants, such as carbon monoxide and oxides of nitrogen, in the exhaust gases.

Compared to conventional burners, however, these new burners suffer a major disadvantage: their performance is much more sensitive to variations in the volumetric ratio of air to gas in

th combustible mixture. To ensure a performance which is safe and satisfactory steps must be taken to ensur that the air/gas ratio always remains within a relatively narrow band of values, and ideally within the range 130-140% of the value theoretically necessary for complete combustion of the fuel gas being burned. This means that when the rate of heat release - and so, the gas flowrate - must be widely variable, the flowrate of the combustion air must alter approximately in step with changes in the gas flowrate. Furthermore, even when the gas flowrate is not variable major changes in the air/gas ratio should not be allowed to follow from alterations in fan performance (due to tolerances in manufacture, or changes in flow density caused by changes in temperature or altitude), or from variations in the flow resistance characteristics of the heating appliance, associated with the use of flueing of a length variable according to the position of the heating appliance within the dwelling. Finally account should be taken of the influence, on the <u>effective</u> value of the air/gas ratio, of changes in the theoretical air requirement for complete combustion of the fuel gas. For a premixture of pure air and fuel gas, at a common temperature and pressure, the <u>effective</u> value of the air/gas ratio may be defined by the following relationship:

$$R_{eff} = \frac{S_{nom} \times R_{act}}{S_{act}}$$

Where R_{eff} = <u>effective</u> value of the air/gas ratio in the combustible mixture.

R_{act} = _actual_ value of the air/gas ratio in the mixture as supplied to the burn r.

S_{nom} = theoretical air/gas ratio for complete combustion of fuel gas of a stated _nominal_ composition.

S_{act} = theoretical air/gas ratio for complete combustion of the _actual_ fuel gas supplied.

For instance, should there be a reduction from nominal of 10% in the theoretical air requirement of the fuel gas (caused for example by an increased proportion of inert constituents therein) there must be, for any given flowrate of the gas, a 10% reduction in the corresponding air flowrate in order to maintain the _effective_ air/gas ratio unaltered by the change of fuel gas properties.

Fully automatic burner controllers invariably embody means for detecting the continued existence of flame during "burner on" periods. With a fully-premixed burner in an enclosed combustion chamber, flame will cease to exist in the vicinity of the detector when, relative to the ideal range of values stated above, the air/gas ratio becomes either excessive (e.g. 40% high) or grossly deficient (e.g. 60% low). In either instance the burner controller will then act to prevent any significant danger arising. Unfortunately with less extreme errors in the air/gas ratio, the flame detector may not respond. In particular, there will be no loss of flame at an air/gas ratio within the range 90-110% of the stoichiometric value (i.e. the value theoretically necessary for complete combustion of the particular fuel gas being burned). However continued operation of the burner may

result in damage to the burner its lf and/or to the h ating appliance; and in the sub-stoichiometric case, toxic concentrations of carbon monoxide will be discharged to the atmosphere.

To provide protection against this eventuality, apparatus may be employed for detecting the effective value of the air/gas ratio and taking corrective action as necessary to maintain it at the desired value. For detection in general a sensor is provided for measuring the concentration of oxygen in the products of combustion, this concentration being directly related to the effective value of the air/gas ratio. Such an approach allows full account to be taken of all the factors which can affect the ratio, and may be considered an ideal technical solution. Unfortunately, the use of oxygen-sensing techniques is at present costly, and appears likely to remain so despite considerable effort and expenditure to alter this situation. Furthermore in the event of a partial rupture in certain critical sealing components there is a potential, in the cheaper types of sensor, for failure to danger. This can be accommodated safely by the use of special techniques in the burner controller preventing the burner from operating until the faulty sensor has been replaced; but such a failure potential is disadvantageous, because it may lead to complaints from users concerning apparent unreliability of the heating appliance and the cost of replacement sensors.

It is an object of the present invention to provide apparatus which is more reliable and cheaper than the conventional

apparatus for detecting the effectiv volumetric ratio of air to fuel gas in the combustibl mixtur supplied to a burner in a heating appliance so overcoming the disadvantages of the conventional apparatus.

According to one aspect of the present invention there is provided apparatus for detecting the effective value of the ratio of air to fuel gas in a combustible mixture supplied to a first burner in a heating appliance, the apparatus comprising a second burner, which provides a flame which in use is located in the path of the products of combustion from the relatively larger flame from the first burner, means for sensing the intensity of light emission from the second burner flame while the first burner is firing and means responsive to the sensing means for providing an output signal, the level of which varies with the intensity of light emission.

Preferably the means for sensing the intensity of light emission is a photoelectric cell.

Suitably the means responsive to the sensing means is circuitry adapted to provide an output voltage signal varying with the intensity of light emission from the pilot flame.

Conveniently the means responsive to the photoelectric cell is circuitry of which the photoelectric cell forms a part, the circuitry being adapted to provide an output voltage signal varying with the resistance f the phot electric cell.

Most advantageously th first burner is a fully premixed burner.

Preferably the second burner provides the ignition means for the first burner.

Suitably control means is provided for controlling the rate of air flow to the first burner in accordance with the magnitude of the output voltage such that the effective value of the air/gas ratio does not fall below a lower limit.

The control means conveniently controls the rate of air flow such that the effective value of the air/gas ratio does not rise above an upper limit.

The control means may include a variable speed fan.

The control means may include one or more Schmitt triggers for responding to the magnitude of the output voltage thereby to control the effective value of the air/gas ratio.

The invention will now be particularly described with reference to:-

Figure 1 which shows schematically the relationship between the aeration percentage (explained subsequently) of the pilot flame and the oxygen concentration in the combustion products from the main burner,

Figure 2 which shows schematically th relationship betwe n th intensity of light from the pilot flam and the oxygen concentration in the combustion products from the main burner,

Figure 3 shows a schematic representation of the apparatus in an enclosing combustion apparatus,

Figure 4 shows a circuit for providing an output signal, the level of which is dependent upon the effective value of the ratio of air to fuel gas in the combustible mixture supplied to the first (main) burner,

Figure 5 shows the spectral response of a suitable, commercially available photoelectric cell,

Figure 6 shows a circuit for controlling a variable speed fan in accordance with the output voltage Vout, and

Figure 7 shows the variation of Vout with the aeration percentage of the main flame as the basis for control of this aeration by the Schmitt triggers.

In order to illustrate the principles underlying the invention, consider first a partially-aerated flame in which only a proportion of the air theoretically required for complete combustion is premixed with the fuel gas within the burner, the remainder of the necessary air being entrained into the burning flame from th surrounding environment as the reaction proceeds.

Wh n burning natural gas th proportion of air premixed with the gas (termed "primary a ration") is normally in the r gion of 45-50% of the stoichiometric requirement, as this provides a flame which is of optimum characteristics for all applications except those needing the flame to be visible, for example decorative effect gas fires. In the latter the primary aeration is lower to permit the formation of soot which, in burning, emits a characteristic yellow light. The lower the primary aeration, the slower the process of soot burnout becomes, and the larger and brighter the resulting flame is.

The soot-forming tendency - referred to as "yellow tipping" - is influenced also by the oxygen concentration in, and the temperature of, the environment around the flame. With a given primary aeration, a decrease in the ambient oxygen concentration will increase the sooting propensity; an increase in the ambient temperature will have the opposite effect. The fuel gas composition is also of significance, the presence of higher hydrocarbons such as propane increasing the tendency for yellow tipping to occur.

Consider, now, a small pilot flame of low primary aeration arranged to subsist within products of combustion from another flame, the latter burning with an air supply exceeding the stoichiometric requirement and, therefore, having unutilised oxygen in the combustion products. Following from the above principles, there will be a relationship between, on the one hand, the oxygen concentration in and temperature of the main

burner combustion products and, on the other hand, a limiting value f primary aeration in the pilot flame at which sooting is just avoided. Now, in the absence of any cooling, the temperature of, and oxygen concentration in, the combustion products from the super-stoichiometric flame will be uniquely related. In this case, the limiting aeration of the pilot flame may be correlated, without loss of accuracy, only to the oxygen concentration in the combustion products from the main burner. The general form of the relationship is shown in Figure 1.

To make practical use of this behaviour, one may observe the intensity of the light emitted from the interaction between the pilot flame and the surrounding combustion products. Figure 2 shows schematically a correlation between the light intensity from the pilot flame and the oxygen concentration in the products from the larger flame, as a function of the primary aeration of the pilot flame. For a given pilot aeration, the light intensity rises rapidly when the oxygen content of the surrounding combustion products falls below a certain value. Alternatively, at a given oxygen concentration in the products, the light intensity increases as the aeration of the pilot flame is reduced. Given a suitable choice of pilot flame aeration, a standard photoelectric cell will suffice to measure the light output.

When these principles are applied in a burner control system, the design must ensure that, under all permitted operating circumstances, the light output from the pilot flame is

detectabl by the photocell: this enables th control system t prove that the pilot is in exist nc and ready to detect the air/gas ratio at the main burner. For safety, failure to detect the pilot when the main burner is alight must result in shutdown of the main burner by the control system.

The technique described may, of course, be applied to monitor <u>any</u> burner designed to operate with unused oxygen in the products of combustion. However, the greatest benefit arises in the case of fully-premixed burners, because of the relative sensitivity of such burners to changes in the effective value of the air/gas ratio in the mixture delivered to the flame, as described earlier.

Referring to Figure 3, there is provided (for the purpose of illustrating the operation of the invention) a first or main burner 1, the apparatus for detecting the effective value of the air/gas ratio comprising a second or pilot burner 2 mounted above the main burner 1 and a photoelectric cell 3 mounted so as to receive the light emission from the flame 4 of the pilot burner 2.

The main burner 1 is mounted at the open lower end 5 of a stainless steel chamber 6 which like the burner 1 is rectangular in cross-section as viewed from above. The chamber 6 has an open upper end 7 and serves as a combustion chamber for the burner 1 and as a flue for removal of the combustion products. The height of the chamber is sufficient to prevent entrainment of atmospheric air into the chamber 6 via the open upper end 7.

The main burner 1 is of the fully pr mix d type in which the fuel gas and air are premixed in a chamber (not shown) befor being introduced into the main burner inlet pipe 8. The surface 9 of the burner 1 comprises a slotted ceramic slab of a known type, the slots being rectangular in section as viewed from above the burner surface 9. The main burner 1 has a flange 10 by which it can be secured via a sealing gasket 11 to a corresponding flange 12 around the lower end 5 of the chamber 6.

The second or pilot burner 2 has a portion 13 which extends through an aperture in a side wall 14 of the chamber 6. The pilot burner 2 comprises a length of stainless steel tubing, the end 15 of which is partially flattened to generate a pilot flame 4 of roughly two dimensional character. To offset the buoyancy of the pilot flame 4 and to resist the disruption of the pilot flame 4 by the relatively high velocity stream from the main burner 1, the pilot tube 2 is as shown angled downwardly so that the flame 4 discharges initially at an angle of 30° below the horizontal along the longitudinal centre line of the main burner 1. Like the main burner 1, the pilot burner 2 is also supplied with an air/gas premixture. In practice the ratio of air to gas in the main burner 1 is most advantageously about 130% of the stoichiometric requirement, i.e. the volume flow rate of air should be about 30% in excess of that theoretically necessary to ensure complete combustion of the gas supplied. In the pilot burner, however, the air/gas ratio in the premixture is much less than the stoichiometric value and should normally be in the range 20 to 30% of this.

Mounted abov the chamber 6 and to on sid of the side wall 16 opposite th pilot burn r 2 is the photoelectric cell 3 located as a close fit within a tubular tunnel 17. The tunnel 17 is angled downwardly and the photoelectric cell 3 is mounted such as to ensure that the cell 3 views only the pilot flame 4 while keeping the cell 3 clear of the very hot stream of combustion products issuing from the top 7 of the chamber 6.

Referring to Figure 4, the circuit includes the photoelectric cell 3 which is of conventional type, the resistance of the cell 3 varying with the intensity of light it receives in such a way that the resistance falls as the intensity of light emission increases. The photoelectric cell 3 forms a potential divider with resistance 20 (R_1) and variable resistance 21 (RV_1). The voltage is tapped off at the junction between 21 and 3 to provide via resistance 22 (R_2) and variable resistance 23 (RV_2) a positive bias voltage to the base of a conventional NPN transistor 24 (TR_1). This controls current through the collector and emitter of the transistor 24 by way of resistance 25 (R_3), the voltage at the emitter being held substantially constant by a conventional Zener diode 26 (D_1).

As can be seen the resistances 20 and 25 are connected to a positive line 26 supplying a positive supply voltage +Vs while the photoelectric cell 3 and the diode 26 are connected to an earthed line 27. An output voltage +Vout is tapped off at line 28 at the junction between resistance 25 and transistor 24.

In us as the lectrical resistance of the photoelectric cell 3 falls with increasing intensity in the level of incident light from the pilot flame, the bias voltage on the base of the transistor 24 also falls. With the voltage on the emitter held substantially constant by the diode 26, the flow of collector current through the transistor 24 decreases and therefore the output voltage +Vout on line 28 rises. The change in output voltage is therefore in the same sense as the change in light intensity incident on the photoelectric cell 3 from the pilot flame. The value of the output voltage varies between an upper and lower limit equal respectively to the supply voltage +Vs and approximately the voltage of the Zener diode 26.

The variable resistances 21, 23 enable the output voltage Vout to be compensated for variations in the performance of individual photocell and transistor samples.

Figure 5 depicts the spectral response of a suitable photoelectric cell. The peak response occurs approximately in the yellow region, and the falloff in response at lesser and greater wavelengths is clearly apparent. This selective response characteristic assists the photocell to discriminate between the yellow light emitted by the pilot flame and the redder light which may emanate from very hot components in the combustion chamber.

Referring to Figure 6, the air flow control means comprises an electrically operable variable speed fan 30 f r delivering air

which may emanate from very hot components in the combustion chamber.

Referring to Figure 6, the air flow control means comprises an electrically operable variable speed fan 30 for delivering air for mixing with the fuel gas supplied to the first burner, a controller 31 for controlling the speed of the fan 30 and two Schmitt triggers 32 and 33 for controlling the fan speed controller 31 in accordance with the magnitude of the output voltage Vout. Both the fan itself, the controller and the triggers may be conventional proprietary items.

The trigger 32 receives an input from Vout and controls the positive terminal of the fan speed controller 31.

The trigger 33 also receives, in parallel with trigger 32, an input from Vout and controls the negative terminal of the fan speed controller 31.

Figure 7 shows graphically how the triggers operate.

In normal operation the value of Vout should be at some desired value such as V_B. Should Vout increase by more than a preset amount to the value V_A the output of trigger 32 will go "high". This signifies that the aeration has decreased, i.e. the effective value of the air/gas ratio has reduced. A "high" output from trigger 32 causes the fan speed to be increased progressively while this output remains "high", to restore the

air/gas ratio to its predetermined lev 1 by incr asing the rate of flow of air to the main burner.

When Vout returns to the value V_B, indicating that the air/gas ratio is again at its desired level, e.g. 30% in excess of the stoichiometric value, the output of trigger 32 will go "low". This causes the fan speed to be held constant at the new (higher) value it has reached. At the same time the output of trigger 33 goes "high".

Should Vout fall from V_B by more than a pre-set amount to the value V_C, the output of trigger 33 will go "low". This signifies that the aeration has increased, i.e. the effective value of the air/gas ratio is increasing. While the output of trigger 33 remains "low", the fan speed controller 31 decreases the fan speed progressively to restore the air/gas ratio to its predetermined level by decreasing the rate of flow of air to the main burner. When Vout eventually returns to the desired value V_B, the output of trigger 33 will go "high". This causes the controller 31 to hold the fan speed constant at the new (lower) value it has attained.

Instead of controlling air flow with a variable-speed fan, alternative means of control could be used, e.g. a variable-position damper or a flue draught control system.

It will be appreciated that instead of controlling the air flow to regulate aeration, the rate of gas flow could be controlled.

In this case, the outputs of the Schmitt trigger would be used to control a variable opening gas valv , via a suitable gas valve controller, and the sense of their operation would be the converse of that described.

The scheme described above has a number of advantages in comparison with oxygen sensing systems, viz:

(i) The technology involved is comparatively simple and well established.

(ii) For any given pilot flame aeration, the output voltage of the detector circuit is consistently related to the effective value of the air/gas ratio at the main burner. This contrasts with the behaviour of schemes directly detecting the oxygen concentration in the combustion products. Here the output voltage may be identical at main burner aerations 5% higher or lower than the stoichiometric, and additional signal processing and verification techniques must be employed to distinguish between these two critically different conditions - the latter being especially hazardous on account of the carbon monoxide necessarily produced. The extra processing adds substantial complexity and cost in the associated electronics.

(iii) Provided the photoelectric cell is prevented from

reaching a temperature xceeding its rated maximum, the r liability of the cell is high: photoelectric flame detection has been a standard feature in oil-fired burners for many years. The less costly types of oxygen sensor are liable to seal failure, at best causing the control system to shut the burner down until a new sensor is fitted, and at worst, leading to incorrect operation of the control system and the emission of toxic gases to the atmosphere.

(iv) The power demand of the associated circuitry is very small compared with that typically necessary when an oxygen sensing system is used. This reduces the cost of the power supply system significantly.

(v) The cost of the photocell and detector circuitry in the scheme described is about 5-10% of the cost of the cheapest available oxygen sensor and its associated electronics. This enables the present scheme to be used as a backup to control systems of the less expensive "open-loop" type, in which there will otherwise be no check on the effective value of the air/gas ratio in the mixture supplied to the main burner.

(vi) If desired, the photocell circuit can be arranged to control a safety shutoff gas valve, such that should +Vout exc d or drop below a pr set figure (indicating

that the effective value of the air/gas ratio has altered by more than some predetermin d amount, e.g. ±15% of the desired normal value), the valve will be closed.

(vii) The pilot flame can, if desired, serve additionally as an "intermittent pilot" for igniting the main burner: this avoids exposing the ignition device to intense heat from the main flame. As an alternative to the use of Schmitt triggers, the control scheme may respond in a continuous fashion to the aeration at the main burner, in the manner of an oxygen sensing system. In principle this would enable the effective value of the air/gas ratio at the main burner to be held up to the design value constantly. Achieving such a performance in practice will be more costly, however, as it will necessitate tight limits on the permissible variations in the performance of the pilot and photoelectric cell.

CLAIMS

1. Apparatus for detecting the effective ratio of air to fuel gas in a combustible mixture supplied to a first burner, the apparatus comprising a second burner which provides a flame which, in use, is located in the path of the combustible products leaving the first burner, means for sensing the intensity of light emission from the second burner flame while the first burner is firing and means responsive to the sensing means for providing an output signal the level of which varies with the effective ratio of air to fuel gas in the mixture supplied to the first burner.

2. Apparatus as claimed in claim 1 in which an enclosure is provided for the burner.

3. Apparatus as claimed in claim 1 or claim 2 in which the means for sensing the intensity of light emission is a photoelectric cell.

4. Apparatus as claimed in any of the preceding claims in which the means responsive to the sensing means is circuitry adapted to provide an output voltage signal varying with the intensity of light emission of the pilot flame.

5. Apparatus as claimed in claim 3 in which the means responsive to the photoelectric c ll is circuitry of which the photoelectric cell forms a part, the circuitry being adapted to provide an output voltage signal varying with the resistance of the photoelectric cell.

6. Apparatus as claimed in any of the preceding claims in which the first burner is a fully premixed burner.

7. Apparatus as claimed in any preceding claim in which the second burner provides the ignition means for the first burner.

8. Apparatus as claimed in claims 4 to 7 in which the control means is provided for controlling the rate of flow of air to the first burner in accordance with the magnitude of the output voltage, such that output voltage does not rise above an upper limit.

9. Apparatus as claimed in claim 8 in which the control means controls the rate of air flow, such that the output voltage does not fall below a lower limit.

10. Apparatus as claimed in claim 8 or claim 9 in which the control means includes a variable speed fan.

11. Apparatus as claimed in claim 10 in which the control means includes one or more Schmitt triggers for responding to the

magnitude of the output voltage thereby to control the effective valu of the air/gas ratio.

12. Apparatus for detecting the effective ratio of air to fuel gas in a manner substantially as hereinbefore described with reference to the drawings.

Pat nts Act 1977
Ex min r's r port t the C mptr ll r under
S cti n 17 (Th Search Report) -22-

Application number

GB 9314214.9

Relevant Technical fields (i) UK Cl (Edition L) G1A (AMF, AHP) F4T (THC, THD, THG) (ii) Int Cl (Edition 5) F23N	Search Examiner DR H J EDWARDS
Databases (see over) (i) UK Patent Office (ii) ONLINE DATABASES: WPI	Date of Search 22 SEPTEMBER 1993

Documents considered relevant following a search in respect of claims 1 TO 12

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
	NONE	

SF2(p)

SJ - doc99\fil001198

Category	Identity f document and relevant passages	Relevant t clair

Cat gories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: D cument indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: M mber of the same patent family, corresponding document.

Databases: The UK Patent Office database c mprises classified collecti ns of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are als listed periodically in the Official J urnal (Patents).